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STANDARDIZATION METHODS OF TREE-RING CHRONOLOGIES

Key words: tree-rings, growth indices, standardization: INDEX, ARSTAN, CORRIDOR.

In climatic reconstructions on the basis of ring-width information the choice of a suitable standardization method is of great importance in order to distinguish and remove non-climatic effects caused by biological growth trends, forest stand changes, and various disturbances. Standardized tree-ring chronology has a stationary mean (100%) and a more or less homogeneous variance through time (Fritts, 1976). It permits using statistical methods in the analysis of time series and comparing the research results.

The most popular method of ring-width standardization is based on fitting the mean curve, either graphically or mathematically, to the ring width which is taken as a standard. Standardized values, or growth indices are relative deviations from this standard. Such approach is used at the Laboratory of Tree-Ring Research, University of Arizona (programs INDEX and ARSTAN). The program INDEX is based on fitting a negative exponential, a straight line or a polynomial curve (Graybill, 1982). With the aid of the program ARSTAN a double elimination of non-climatic trends is produced: first a growth function is calculated by fitting an exponential curve or straight line, indexing, and then the remaining trends are excluded by a relatively rigid cubic smoothing spline (Cook, 1985; Holmes et al., 1986). Shiyatov (1972; Шиятов, 1986) proposed another method for the calculation of growth indices which is based on the use of the maximum and minimum possible growth curves. These curves form a strip or a "corridor". The growth index is calculated by dividing the distance between the minimum curve and the ring width by the width of the corridor of the same year. The width of the corridor is taken as 100 or 200% each year.

In connection with Soviet-American investigations in dendrochronology on the project 02.03-21 the necessity of a comparative analysis of these standardization methods has become evident. Such study was carried out by the authors during Shiyatov's visit to the Laboratory of Tree-Ring Research in 1987. For this purpose we used the ring-width data of Siberian larch (*Larix sibirica* Ldb.) growing at the upper timberline in various provinces of the Ural Mountains, but on the same type of soil (abundant running water). The mean chronologies (Table 1) basically reflect the thermal conditions of the summer months (Шиятов, 1986).

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Table 1

Characteristics of the mean tree-ring chronologies

Series code	Province	Latitude North	Longitude East	Altitude, meters	Trees sampled	Chronology time span
S01	Polar Urals	66°50′	65°30′	150—300	21	1541—1968
S08	Subpolar Urals	64°40′	59°50′	550—700	20	1691—1969
S11	North Urals	59°35′	59°10′	800—950	25	1590—1969
S29	South Urals	54°30′	58°50′	1000—1100	11	1770—1972

Three mean chronologies were developed for each of the four single sites: the INDEX chronology (the version of the program INDEX made by Lofgren in 1985), the ARSTAN chronology (the version of the full ARSTAN analysis made by Cook and Holmes in 1986), and the CORRIDOR chronology (calculations made by Shiyatov (Table 2)). In the program ARSTAN the spline stiffness was taken as 100% of the series length. The maximum and minimum possible curves were drawn by hand on the plots of ring widths using a template and ruler.

One can see (Table 2) that the chronologies developed by the corridor method have higher mean sensitivity and standard deviation than the chronologies developed by the programs INDEX and ARSTAN. The greatest differences are in the S29 series, its signal-to-noise ratio is of the lowest value. This is associated with the fact that the corridor "stretches" the extreme values of growth indices, especially in chronologies with relatively weak climatic signal. First order autocorrelation values are practically equal in the chronologies developed by the corridor method and the program INDEX, somewhat lower in ARSTAN chronologies due to the elimination of the influence of the previous year growth on the current year growth (ARMA modeling). Correlation coefficients are very high (from 0.917 to 0.981) among the obtained chronologies. This

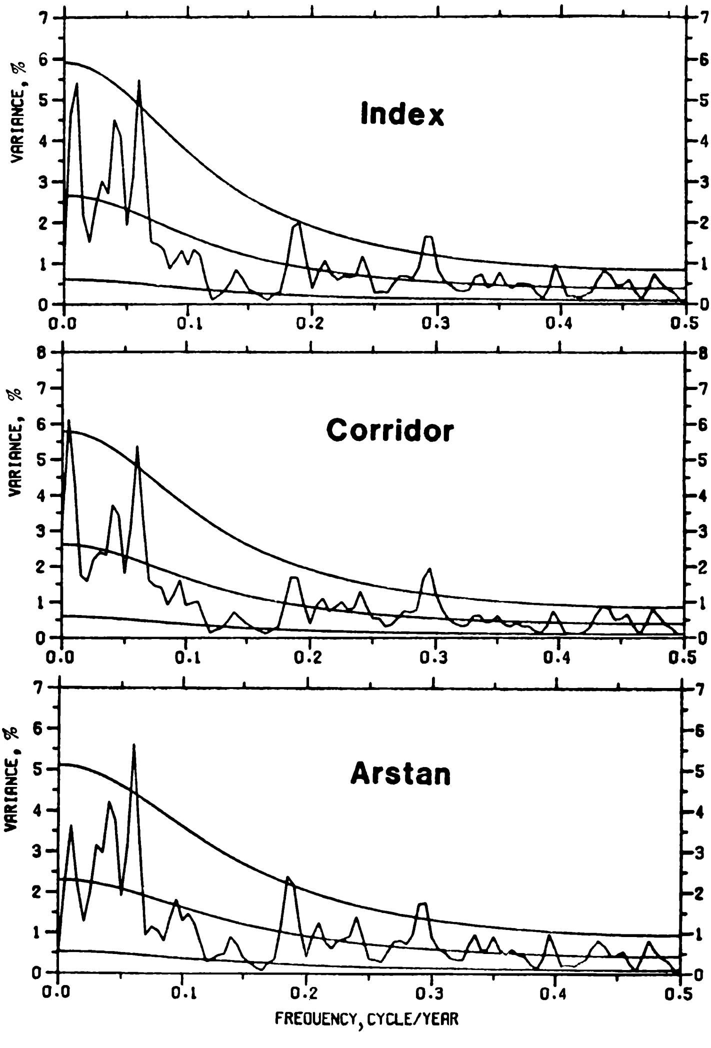
Table 2

Statistics of the mean chronologies developed by the various standardization methods (*C*-CORRIDOR, *I*-INDEX, *A*-ARSTAN)

Series code	Standardization method	Mean sensitivity	Standard deviation	Autocorrelation order 1	Signal-to-noise ratio
S01	*C*	0.41	0.42	0.43	—
	I	0.40	0.42	0.46	—
	A	0.40	0.42	0.47	22.8
S08	*C*	0.39	0.43	0.45	—
	I	0.35	0.40	0.45	—
	A	0.36	0.39	0.39	27.3
S11	*C*	0.35	0.38	0.47	—
	I	0.33	0.37	0.48	—
	A	0.35	0.36	0.39	29.2
S29	*C*	0.31	0.37	0.52	—
	I	0.24	0.29	0.50	—
	A	0.24	0.28	0.45	8.9

is an evidence of the high degree of similarity among the chronologies. Spectral and cross-spectral analyses confirm the great similarity of the chronologies developed by various standardization methods (Fig.). However, the chronologies developed by the program INDEX and especially by the corridor method have more pronounced low-frequency variations than the ARSTAN chronologies.

Thus, the mean tree-ring chronologies developed by the corridor method, the programs INDEX and ARSTAN bear much resemblance to one another and can be compared without restandardization. But if it is necessary to reveal the low-frequency fluctuations of growth indices, the corridor method and the program INDEX are preferable. The effect of such non-climatic factors as phytocoenotic, various non-synchronous disturbances, the effect of previous year growth on the current year growth, is excluded best in the chronologies developed by the program ARSTAN. It is essential that the chronologies developed by the corridor method have the highest sensitivity and dispersion.



Subpolar Urals chronology SO8. Comparison of variance, period: 1691—1968 with 100 lags.

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